University of Cambridge

SOLAR PHYSICS OBSERVATORY

FIFTH ANNUAL REPORT OF THE DIRECTOR OF THE SOLAR PHYSICS OBSERVATORY TO THE SOLAR PHYSICS COMMITTEE

1917 APRIL 1—1918 MARCH 31

Fifth Annual Report of the Director of the Solar Physics Observatory

12 *June* 1918.

The VICE-CHANCELLOR begs leave to publish to the Senate the following Report which the Solar Physics Committee have received from the Director of the Solar Physics Observatory:

The Report here presented relates to the year 1917 April 1 to 1918 March 31.

The Assistant Director, Mr Stratton, has been absent the whole year, with the British Expeditionary Force in France. The First Junior Observer, Mr W. E. Rolston, is also with the Force in France. The Second Junior Observer, Mr W. Moss, still continues his duties in the Inspection Department at Woolwich Arsenal. The Resident Attendant, W. H. Manning, is still engaged in munition work.

Both the Director and Mr C. T. R. Wilson have been engaged in investigations connected with the national defence.

No recent information is available about the apparatus taken to the Crimea in July 1914 and left at Odessa.

A. *Stellar Work.*

β Lyrae. The study of the series of records of the spectrum of the variable star *β Lyrae* has been continued. Out of 76 available photographs secured at South Kensington 22 have been selected as best representing the various phases of the spectra. Photographic enlargements on paper have been made to a uniform scale for the purpose of unravelling the changes in relative position of the bright and dark lines. Information has been gained, chiefly of a qualitative nature, though the measurements made serve to indicate the best epochs for securing new records with comparison spectra in the coming year.

Hydrocarbon bands in stellar spectra of types F to M. The available photographs of stellar spectra of the Harvard types *F* to *M* inclusive have been compared with one another. The chemical origins of the lines have been discussed and the spectra have been arranged in what is considered to be an evolutional series. In this way stellar spectra have been found which appear to fill some of such gaps in the sub-types as are left unfilled in the Harvard Classification. Special attention has been given to the behaviour of the hydrocarbon bands, particularly the isolated group of lines 4323·0 to 4324·5, in the various spectra. It has been found possible to arrange the series in a sequence, which indicates a gradual strengthening of the hydrocarbon lines from the *F* type to the *G* type and a gradual weakening of the same lines from the *G* type to the *M* type.

The stellar work has been in the charge of Mr Baxandall.

B. *Solar Work.*

Spectroheliograph. Photographs of the sun's disc in $K_{2,3,2}$ light have been obtained on 161 days (previous year, 117), and photographs of the prominences at the limb on 153 days (previous year, 104). The work has been in the charge of Mr Butler.

With a few intervals of relative quiescence, the solar activity has been maintained throughout the year, and the epoch of maximum cannot yet be regarded as passed.

The 18-inch and 6-inch mirrors were dismounted on 1918 February 7, and were replaced on February 11 after being resilvered.

The Director of the Kodaikanal Observatory has forwarded 328 spectroheliograms showing the solar disc in calcium ($K_{2,3,2}$) light for the year 1918 January 1—December 31 relating to 328 days. Of the 37 days missed in the Kodaikanal records there are Cambridge records for 14 days, so that solar records of calcium flocculi are available for 342 days in 1917 (previous year, 337).

Study of spectroheliograms. A preliminary examination has been made of the spectroheliograms available for selected years of maximum, minimum and intermediate solar activity. The investigation constitutes a search for evidence pointing to the possible existence, outside the sun's limb, of a stratum which may be regarded as a limit towards which the smaller prominences tend to be ejected. There are very frequent signs of portions of bright arc-like strata, concentric with the sun's limb, extending for not inconsiderable distances along the limb. Such stratiform arcs are doubtless the bright envelopes of uprising calcium over considerable regions of the sun's surface and only capable of being studied at the sun's limb. The Kodaikanal spectroheliograms of the

solar disc usually show traces of the brighter prominences and are valuable in a preliminary search of this kind. The Cambridge records taken in a much less clear sky seldom afford the material required for the research, and it is to be regretted that in war conditions it has not been possible to remodel the old spectroheliograph with largely increased dispersive power, so that the spectroheliograms of the prominences should be of service in this respect.

Photoheliograms. Daily photographs taken with the Dallmeyer photoheliograph at Dehra Dûn have been received. The negatives are stored at the Science Museum, South Kensington. The positive prints on paper have been received from Dehra Dûn, but the work of mounting is in abeyance as in the past two years.

Spectra of sun-spots. In the autumn months many photographs of spectra of sun-spots chiefly in the region of λ 5300—5500 were obtained with the M^c^Clean solar instruments. A few records have been secured also in the region λ 4200—4400 for special study of the behaviour of the hydrocarbon bands in that region. So far as the evidence goes at present, it appears that these bands are hardly affected in the spectra of sun-spots.

Convenient arrangements have been successfully developed by the Director for securing photographs of the sun's disc in the integrated photographic rays with the 60 ft. lens of the same installation. The photographs are taken on slow bromide paper, and were intended to serve as rough records for indicating the distribution of the spots, and of the special features which have been studied spectroscopically. They have however proved to be so satisfactory also in their presentation of the faculæ over the sun's surface, as well near the centre of the disc as near the limb, that it seemed desirable to develope the method so as to find the conditions for the best definition attainable with the apparatus. The records now obtained seem likely to be of value in the elucidation of the relation between faculæ and flocculi, and also possibly as regards the mode of circulation in the solar atmosphere. Records secured in February 1918 exhibit long trails of faculæ extending over more than 180° in solar longitude, in northern latitudes considerably higher than the active spot zone; and spectroheliograms obtained on the same days exhibit trails of calcium in similar positions.

A comprehensive comparison table has been prepared, by Mr Baxandall, of the affected lines in spot spectra which have been recorded by various observers. These are given in order of wave-length and cover the region of the spectrum λ 3900 to λ 7200. The chemical origins of these lines have been revised by reference to the most recent and trustworthy records of spectra studied in laboratories. The relative intensities of the affected lines in spot and sun in the region λ 4600 to λ 7200 have been redetermined from Hale's maps of spot spectra, Fowler's method of equating the spot intensity with that of a neighbouring Fraunhofer line being used.

In addition to the identified bands in sun-spot spectra, there are portions of the spectrum which are apparently of a banded nature, but have not been traced to their chemical origin. Detailed search has been made amongst records of banded spectra studied in laboratories, both published and unpublished, for the purpose of identifying the origin of some of these spot bands; but up to the present the search has proved fruitless.

C. *Meteorological Physics.*

Investigations in Atmospheric Electricity. Mr C. T. R. Wilson has continued his researches. Apparatus for automatically recording the electrical phenomena of thunderstorms was in use throughout the summer months of 1917, and a large amount of material was obtained: this has now been reduced and is nearly ready for publication.

Records were obtained by means of this apparatus during ten storms. The sign and magnitude of the rapid changes of potential gradient accompanying more than 700 lightning flashes were recorded.

In the majority of cases—rather more than 60 per cent.—these sudden changes of field were 'positive,' i.e. a potential gradient increasing upward was suddenly superimposed on the already existing positive or negative or neutral vertical electric field near the earth's surface, suggesting the discharge to earth of a negatively charged cloud.

When thunder was audible, the beginning—and in many cases the end also—of each successive peal was marked on the trace by momentarily interrupting the illumination. When the discharges followed in rapid succession it was frequently impossible to identify with certainty the thunder corresponding to a given lightning discharge, but a considerable number of records were free from ambiguity in this respect. Information was thus obtained as to the magnitude of the changes of field due to lightning discharges at different distances. For both positive and negative discharges curves were constructed showing the mean change of field due to lightning flashes at distances of successive kilometres. These curves are in general agreement with the theoretical curves which give the change of field at different distances from a lightning flash on the assumption that it consists of a discharge to earth of a quantity q of electricity from a height h. They indicate mean values of q and h of approximately 20 coulombs and 5 kilometres respectively.

If it is assumed that the charge is uniformly distributed in a sphere, the radius of the sphere would have to be less than 400 metres in order that the maximum value of the field should reach the limit required for a spark discharge.

In many cases the records show that the lightning flashes were multiple, indicating a succession of sudden changes or reversals of the field. The intervals between these sudden changes are frequently about one or two-tenths of a second—a time comparable with that taken by an electric wave to travel completely round the earth.

The majority of the discharges recorded were simple, the record showing an instantaneous change of potential gradient, followed by a characteristic recovery curve. From these curves information is obtained (1) as to the rate of production of the charge in the thundercloud by precipitation or otherwise, and (2) as to the rate at which the charge thus accumulated tends to be dissipated by ionisation currents under the action of the electric field developed. The initial rate of reproduction of the field of the storm immediately after a discharge, expressed as a fraction of the field destroyed by the discharge, varied between ·03 and 1 per second—in other words, in the absence of the neutralising ionisation current the intervals between the successive discharges would have varied between 1 second and 30 seconds. In several storms the field reached a nearly steady value between the successive discharges, i.e. the ionisation current was almost sufficient to prevent the field attaining the limit necessary for the passage of a discharge: a slightly smaller rate of production of the field would have been insufficient to produce any lightning discharges. It is evident that the actual interval between the discharges will be very long when the critical rate of production of the field is only slightly exceeded, and will diminish very rapidly as the rate increases beyond this limit.

Ignoring the normal atmospheric ionisation which is probably relatively negligible, we may consider ions from three sources as likely to contribute to the compensating current which tends to discharge a thunder cloud. These are (1) ions whose liberation is directly associated with the processes which give rise to the electric field of the storm, e.g. ions produced by splashing within the shower or at the surface of the ground; (2) ions liberated by point discharges from trees, lightning conductors, &c.; (3) ions from the upper atmosphere, these being probably mainly produced by the action of the electric field of the cloud. The last-named source of ions is of special interest on account of its bearing on the general electrification of the atmosphere, on the propagation of "atmospherics" or "strays," and on auroral phenomena. The electric field over a localised charge—such as has been above implied as existing in the head of a thunder cloud—will fall off rapidly with height, finally according to the inverse cube law; but, the density of the atmosphere falling off still more rapidly, the ratio of the strength of field to the density of the air will above a certain height reach the limit required for ionisation by collision. With a charge of 20 coulombs at 5 kilometres above the ground this limit would be reached at about 50 kilometres. On account of the large difference in the mobility of the positive and negative ions in the upper atmosphere—the negative ions being mainly in the condition of free electrons—the downward stream of negative ions to a positively charged cloud is likely to carry a very much greater current (of positive electricity to the upper atmosphere) than that carried by the downward stream of positive ions to a negatively charged cloud. The addition of another possible source of the normal excess of positive electricity in the atmosphere to the many already brought forward is thus suggested.

Mr Wilson has been invited to give assistance to the Advisory Committee for Aeronautics on points with which he is specially conversant.

D. *Work in the Laboratory.*

With the modified small Huggins spectrograph, photographs of spark spectra given by several combinations of metallic poles in air, steam, coal gas, have been taken, in connection with the investigation of hydrocarbon spectra, special attention being devoted to the lines modified at the positive and negative poles.

E. *Miscellaneous.*

A number of valuable publications have been received in the course of the year, and the Director desires to record his grateful acknowledgments to the donors. The publication of the list is deferred.

H. F. NEWALL.

Solar Physics Observatory,
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